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Number 176

SOME RESULTS AT SMITHSONIAN OBSERVING STATIONS

by

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STATISTICS ON CLOUD COVER AT BAKER-NUNN OBSERVING SITES *N65-31269*

Peter Brand and Leonard Solomon

RESIDUALS IN FIELD-REDUCED OBSERVATIONS *N65-31270*

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PHOTOGRAPHY OF CHEMILUMINESCENT STUDIES OF UPPER ATMOSPHERE WIND PHENOMENA

John Mazzotta, Roy Proctor, and James Latimer *N65-31271*

BAKER-NUNN TRACKING OF THE AIR DENSITY EXPLORER BALLOON AND THE INJUN  
EXPLORER SPACECRAFT

*N65-31272*

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STATISTICS ON CLOUD COVER AT BAKER-NUNN OBSERVING SITES<sup>1</sup>

by

N65 31269

Peter Brand<sup>2</sup> and Leonard Solomon<sup>3</sup>

Satellite photography at Baker-Nunn camera stations is based on predictions computed in Cambridge and sent to each station. The predictions generally are evenly grouped in evening and morning hours, with lower density in the midnight sky. It is rare, however, for the midnight hours to be completely devoid of predictions. The number of predictions varies from 15 to 35 per station per night.

The "Percent Not Attempted Due to Clouds" given here refers to those predicted satellite transits for which no film was exposed because of obscuring clouds in the sky area of interest. This is a lower limit to the actual cloud cover hindrance, as satellite photography is occasionally attempted through thin or broken clouds.

Statistics for ten of the stations are presented here, covering the years 1962 and 1963. Data for 1964 is not yet complete in this form.

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<sup>1</sup>This work was supported in part by grant NsG 87-60 from the National Aeronautics and Space Administration.

<sup>2</sup>Mechanical Engineer, Station Operations Division, Smithsonian Astrophysical Observatory.

<sup>3</sup>Astronomer, Station Operations Division; Chief, Data Division, Smithsonian Astrophysical Observatory.



Table 1.--Percent not attempted due to clouds

Station Coordinates	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
New Mexico 253° 27' (E) +32° 25'	1962 36 1963 34	25 27	27 21	15 29	5 30	12 13	49 48	32 57	48 28	19 16	26 27	22 17
South Africa 028° 15' (E) -25° 58'	1962 42 1963 50	29 23	31 27	26 28	4 15	6 21	1 20	5 2	8 7	29 30	53 55	37 49
Australia 136° 46' (E) -31° 06'	1962 32 1963 16	21 22	21 22	9 22	34 51	12 35	22 47	22 21	27 18	38 17	15 18	18 22
Spain 353° 48' (E) +36° 28'	1962 52 1963 72	32 49	81 39	43 39	33 35	15 32	21 4	15 19	34 22	47 19	40 60	43 45
Peru 288° 30' (E) -16° 28'	1962 81 1963 88	71 95	56 63	38 56	10 23	2 2	5 6	6 15	35 21	22 26	42 13	55 52
Iran 052° 31' (E) +29° 38'	1962 28 1963 17	44 40	33 30	54 47	10 30	1 7	18 15	16 23	03 1	nil 12	14 35	38 22
Curaçao 291° 10' (E) +12° 05'	1962 52 1963 70	43 59	56 51	53 68	74 70	66 40	46 64	38 55	60 63	39 50	45 65	50 62
Florida 279° 53' (E) +27° 01'	1962 55 1963 57	40 58	62 47	55 28	36 50	61 42	41 44	55 29	52 49	45 32	55 49	43 43
Argentina 291° 54' (E) -31° 57'	1962 53 1963 *	52 35	38 40	72 27	51 39	27 33	39 36	32 32	22 57	29 46	35 46	43 30
Hawaii 203° 45' (E) +20° 43'	1962 23 1963 59	41 17	56 70	39 78	33 52	5 28	38 29	18 23	20 39	16 39	26 32	33 30

\* No photography attempted for a 3 week period when the mirror was removed for realuminizing.

65-31270

RESIDUALS IN FIELD-REDUCED OBSERVATIONS<sup>1</sup>

by

Leonard Solomon<sup>2</sup>

We have compared field-reduced observations with photoreduced observations and the orbits derived from them to determine the approximate error to be expected in any field-reduced observations. This was done as a comparison with previously estimated values. Four periods of coverage of roughly one month each in 1962 and 1963 were taken, two of 1960  $\alpha$ 2, one each of 1961  $\alpha$ 81 and 1959  $\alpha$ 1. Photoreduced observations were used to derive the best possible orbits. We then used the same orbits as a standard and found new residuals of the same photoreduced observations along with the same period's field-reduced observations, station by station. By using a priori low weight for the field-reduced data, their effect on the orbit was made negligible.

As a measure of the precision of each field measurement we take the difference between precisely-reduced and field-reduced residual ( $|\sigma_f - \sigma_p|$ ), where the observations are made within one minute of one another (i.e., on the same film). Each such difference is given unit weight in computing the mean, with the value used in each case being taken when the observations were closest to epoch for the particular orbit determination set. Table I shows the results for all Baker-Nunn stations. Note that the estimated error is quite close to the estimated BD chart plotting error of 1 minute of arc; hence we can now state that field-reduced accuracies are at least partially limited by chart accuracy.

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<sup>1</sup>This work was supported in part by grant Nsg 87-60 from the National Aeronautics and Space Administration.

<sup>2</sup>Chief, Data Division; Astronomer, Station Operations Division, Smithsonian Astrophysical Observatory.

Table 1.--Residuals--Field minus precisely-reduced

<u>Station</u>	<u>No. Obs.</u>	<u><math>\Delta</math> Dec</u>	<u><math>\Delta</math> R.A.</u>
1	60	56".6	63".3
2	76	64.1	62.3
3	71	51.8	58.2
4	67	57.4	62.1
5	14	54.3	79.7
6	41	49.1	65.1
7	28	67.0	90.2
8	38	63.8	71.8
9	40	62.4	50.2
10	44	62.8	60.6
11	72	72.2	61.7
12	28	68.5	59.4
Total	579	$60.9 \pm 7.0$	$63.4 \pm 10.8$

# PHOTOGRAPHY OF CHEMILUMINESCENT STUDIES OF UPPER ATMOSPHERE WIND PHENOMENA<sup>1</sup>

by

John Mazzotta<sup>2</sup>, Roy Proctor<sup>3</sup>, and James Latimer<sup>4</sup>

65-31271

**Abstract.**--Several of the SAO Satellite Tracking stations have participated in studies of upper atmosphere wind phenomena through the use of rocket-released chemiluminescent trails. Using the results of early attempts, station personnel have devised new techniques for photographing these trails.

## Introduction

In recent years, a variety of experiments have been conducted in an international effort to study upper atmosphere wind phenomena. To investigate properties such as wind velocities, shear, turbulence, and diffusion, rocket-borne devices capable of creating visible trails in the atmosphere have been perfected. Sodium vapors and trimethylene aluminum are two agents used to create these trails. The former is effective only during twilight, roughly 20 to 40 minutes at sunrise and sunset, when the cloud is illuminated by the sun against the dark background of the sky. The latter, on the other hand, generates a visible trail under full night conditions.

---

1

Supported by grant number NsG 87-60 from the National Aeronautics and Space Administration.

2

Observer, Hawaii, U.S.A.

3

Observer, Wallops Island, Virginia, U.S.A.

4

Observer, Argentina

Because of ~~their~~ proximity to various launch sites throughout the world, the Astrophysical Observing Stations of the Smithsonian Institution have been asked to participate in the program by obtaining Baker-Nunn photographs of the various chemical releases. Such services are expected under the provisions of agreements with some host countries, and the Observatory is always anxious to cooperate in worthy scientific experiments. This report includes the results obtained by the stations in Argentina and Hawaii, covering a series of shots conducted by the Argentine Space Commission and the Sandia Corporation, and the Wallops Island station. Each report outlines the techniques used, the problems encountered, and suggested solutions for overcoming these problems.

#### Sodium Cloud Experiment - Argentine Space Commission

The Argentine Space Commission conducted a series of three launches on 4, 5 and 6 November 1964, from Chamental in the province of La Rioja approximately 200 kms from Villa Dolores, the station site. The first launch, fired on 4 November, could not be photographed due to a solid cloud cover over the station site. However, photographs were obtained of the second and third launches which were conducted during evening and morning twilights, respectively.

The evening shot was photographed from 23:17:42, when the rocket's afterblast and the embryonic sodium trail first became visible, until 23:36:10, when the trails either dissipated or became invisible due to darkness. (See Figures 1, 2, and 3.) The morning shot was photographed from 08:34:32 until 08:50:52. More detailed information of the photography and the results is found in Table 1.

Approximately the first nine minutes of coverage by the Baker-Nunn camera produce results of good quality. The remainder, though of qualitative interest, will not be of sufficient contrast to give much quantitative information. It should be noted here that in each shot the time of launch directly affected the photographic results since the last half lost definition and contrast. This was due in part to expansion and diffusion, and in the case of the evening shot to lack of illumination as the twilight grew darker, and for the morning shot excess illumination as the twilight grew brighter.

In the evening firing, the rocket was sighted about one and one-half minutes after launch time, but the morning test was not visible until some two and one-half minutes after launching. Apparently the morning shot, unlike that of the evening, experienced a delay in sodium ejection until the rocket was practically out of the turbulent zone. The first frames of the morning shot show nothing but a "blob" at the top of the arc with no turbulence. For this reason the camera was moved to catch the descending column. Somewhat later, a different camera orientation showed turbulence in both the ascent and descent columns.

Two problems plague the operator constantly during the photography of an object such as this. The first is the size of the field to be photographed. At our range something in the order of  $30^{\circ} \times 30^{\circ}$  would be ideal to give full, uninterrupted, stationary camera coverage of the entire experiment. With the  $5^{\circ} \times 30^{\circ}$  field of the Baker-Nunn, there are several choices of orientation left to the operator; vertical orientation of the "ascent" column, vertical orientation on the "descent" column, or horizontal orientation across both columns. There are obvious disadvantages to each of these choices; for the vertical orientations horizontal movement can, and did, exceed five degrees, while for the horizontal orientation, the vertical area of interest is more than five degrees long.

The second problem concerns the proper exposure time, rate, diaphragm, and filter. This is, of course, something only experience and experimentation can determine. Based on the present results, the following is recommended. Assuming the one frame every eight seconds time interval is satisfactory to those making the measurements, the combination of a 16 cycle rate with an f/4 diaphragm using wratten 23A filters has enough latitude to give excellent results for sky conditions ranging from "bright" to "medium dark." For "dark" sky photography, more experimentation is needed without diaphragm or filter.

#### Trimethylene Aluminum Shots - Sandia Corporation

In conjunction with the Sandia Corporation, the Satellite Tracking Station on Maui employed the Baker-Nunn camera to photograph trimethylene aluminum released from two rockets launched on the island of Kauai (100 miles west of Maui). These launches were at 85 to 150 kms. The trimethylene aluminum which is released from canisters in the twilight hours, after the sun has set, gives a light greenish glow in twilight and a blue-white glow in darkness. Employment of the B-N camera with Royal-X Pan film in the twilight hours is necessarily limited to the use of filters (to improve the contrast between the cloud and the relatively bright twilight sky) and diaphragms (to prevent background fogging). Two diaphragms (f/4.0 and f/8.0) were prepared with Kodak red wratten A-23 filters; this was done with the intention of using the f/8.0 diaphragm and filter in the early twilight, using the f/4.0 diaphragm and filter in the late twilight, and using neither diaphragm nor filter in darkness.

The first shot, 06:18 Z on 1 November 1964, was photographed in complete darkness, three hours after the sun had set. It was photographed with Royal-X Pan film, Kodak batch 283353, at the 16-second cycle rate, with two transports per cycle, using neither diaphragm nor filter. The results were positive, yielding clear definition of the cloud with a good star background. (See Figures 4, 5, and 6.)

The second shot (Figures 6 and 7) occurred at 04:30 Z on 3 November 1964, 75 minutes after the sun had set. The results of this photography with Royal-X Pan recording film, (S0-283) Kodak batch 35, indicate that good results may be obtained through the employment of the following schedule (when shooting into the setting sun). (See Table 2.) Note that times are computed on the basis of sunset at 03:15 Z.

The major problem in this photography is the selection of the proper camera settings, since no settings or look-angles were available. As seen from the tracking station, both rockets had parabolic trajectories. For the first shot, it was during the downward portion of the trajectory that the dense cloud was released (This was clearly distinguishable.). Three of the frames show the rocket releasing the cloud. The material is released in an arc which is apparently almost vertical to the horizon. As it is dispersed by the winds, it appears to move in bands approximately parallel to the horizon. As seen from the tracking station on Maui (elevation 10,000 feet and 100 miles distant from the origination of the launch), the cloud appeared between  $20^{\circ}$  and  $30^{\circ}$  above the horizon, almost due west. The second shot differed from the first in that the cloud was released during the upward portion of the trajectory; the release of the material was also clearly distinguishable in this case.

Details of the results of these shots are listed in Table 3. Two earlier launches were successful, but not photographed by the Maui Satellite Tracking Station, at 04:30 Z on 23 October 1964, and at 06:30 Z on 28 October 1964. The two launches which were photographed were cut short when fog rolled in on the station.

#### Chemiluminescent Photography - Wallops Island

Since December 1963 we have attempted photography on seven sodium launches, the results of which are listed in Table 4.

The successful plates of 5 and 6 November were sent to Dr. McCrosky, who forwarded them to Mr. Beddinger of the Geophysics Corporation of America. We have had no indication of whether the plates were useful to G.C.A. or not.

Through trial and error (mostly error) we have developed quite efficient observing techniques for the sodium rockets. This was made possible by improving our timing methods, modifying the SS and ST cameras, and using the rubberized camera cover (Baker-Nunn type). We can now load and unload the cameras in full daylight, with very little fogging of the film.

With accurate timing and two or more camera stations, we can now show the precise growth of the sodium cloud and reconstruct a three-dimensional model of the cloud from time of ejection until dispersion.

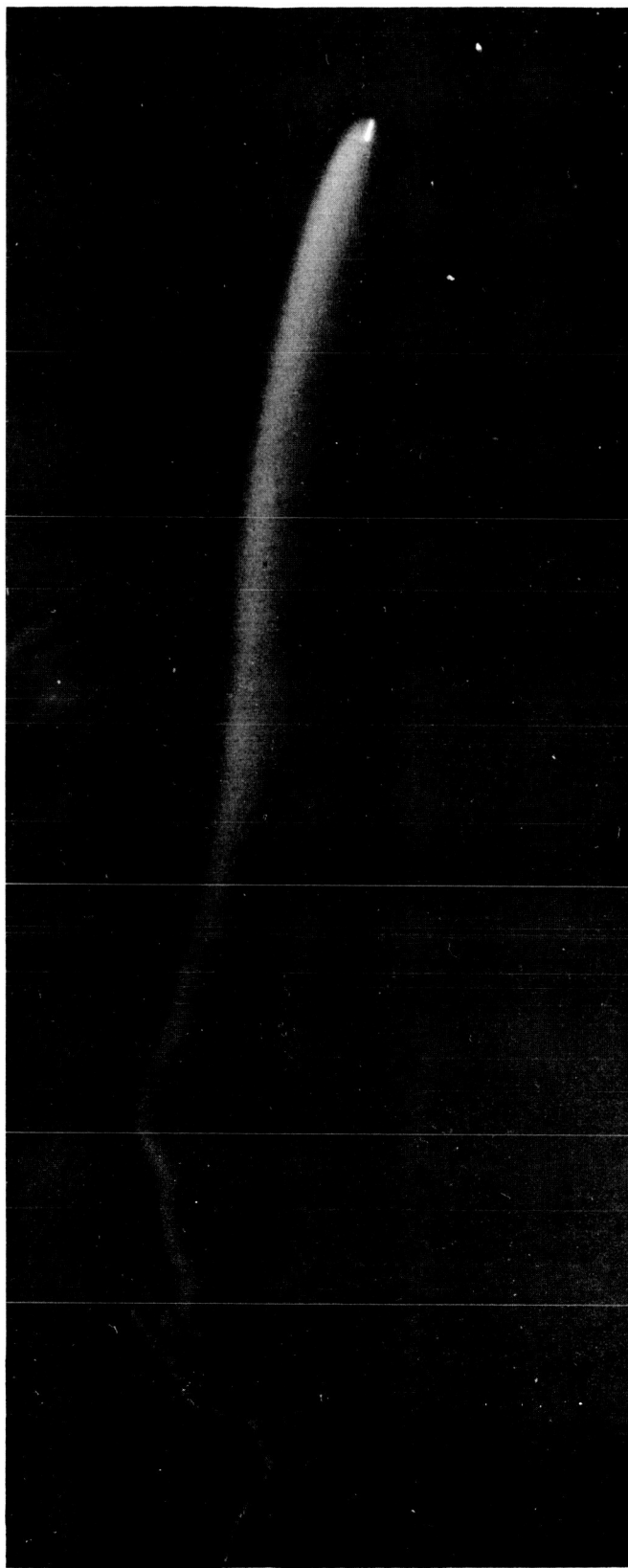


Figure 1.--Evening shot: rocket ascending and sodium trail contortions beginning.





Figure 2.--Evening shot: same region a minute later.

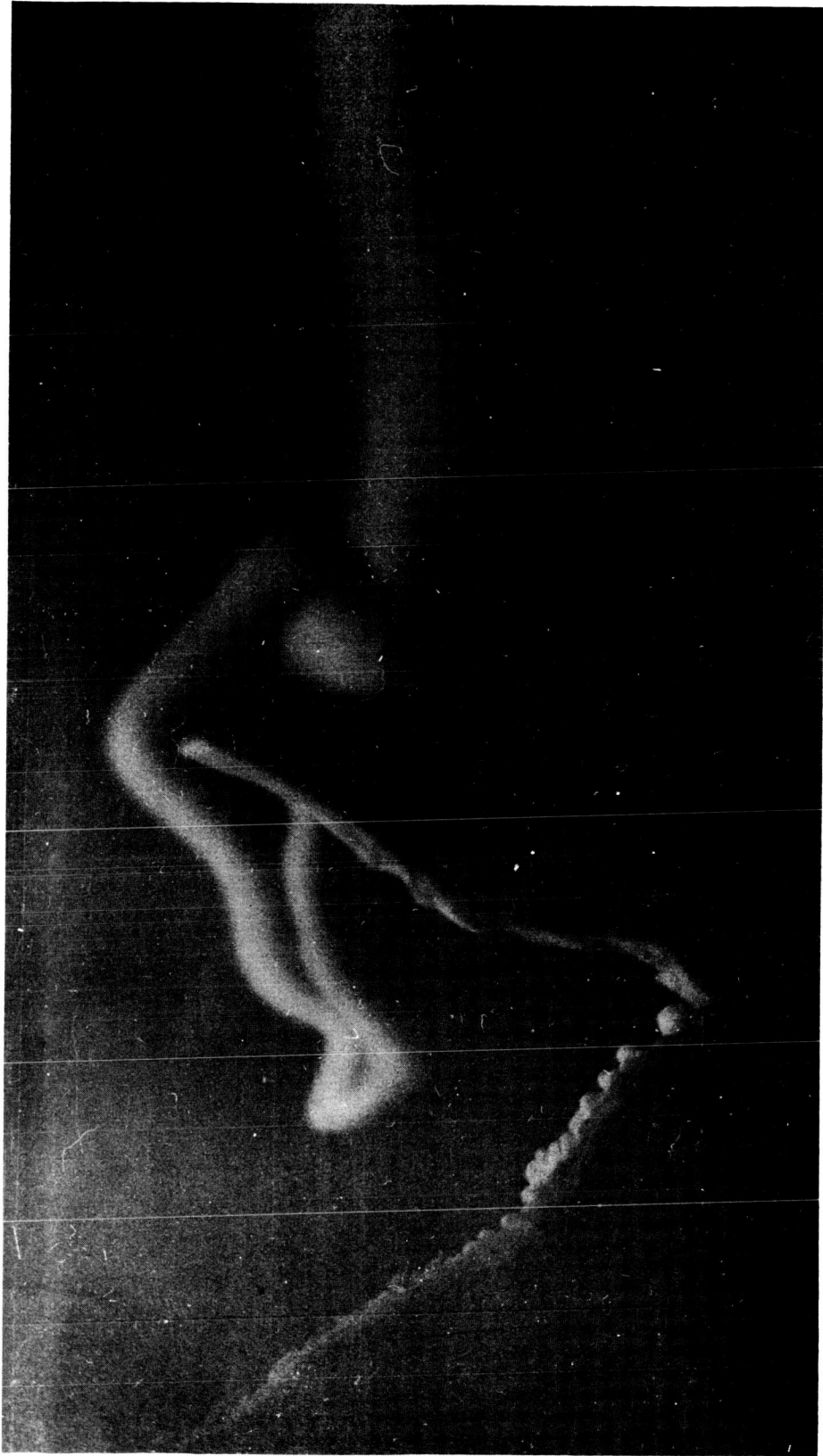


Figure 3.--Evening shot: turbulence in the ascending column.

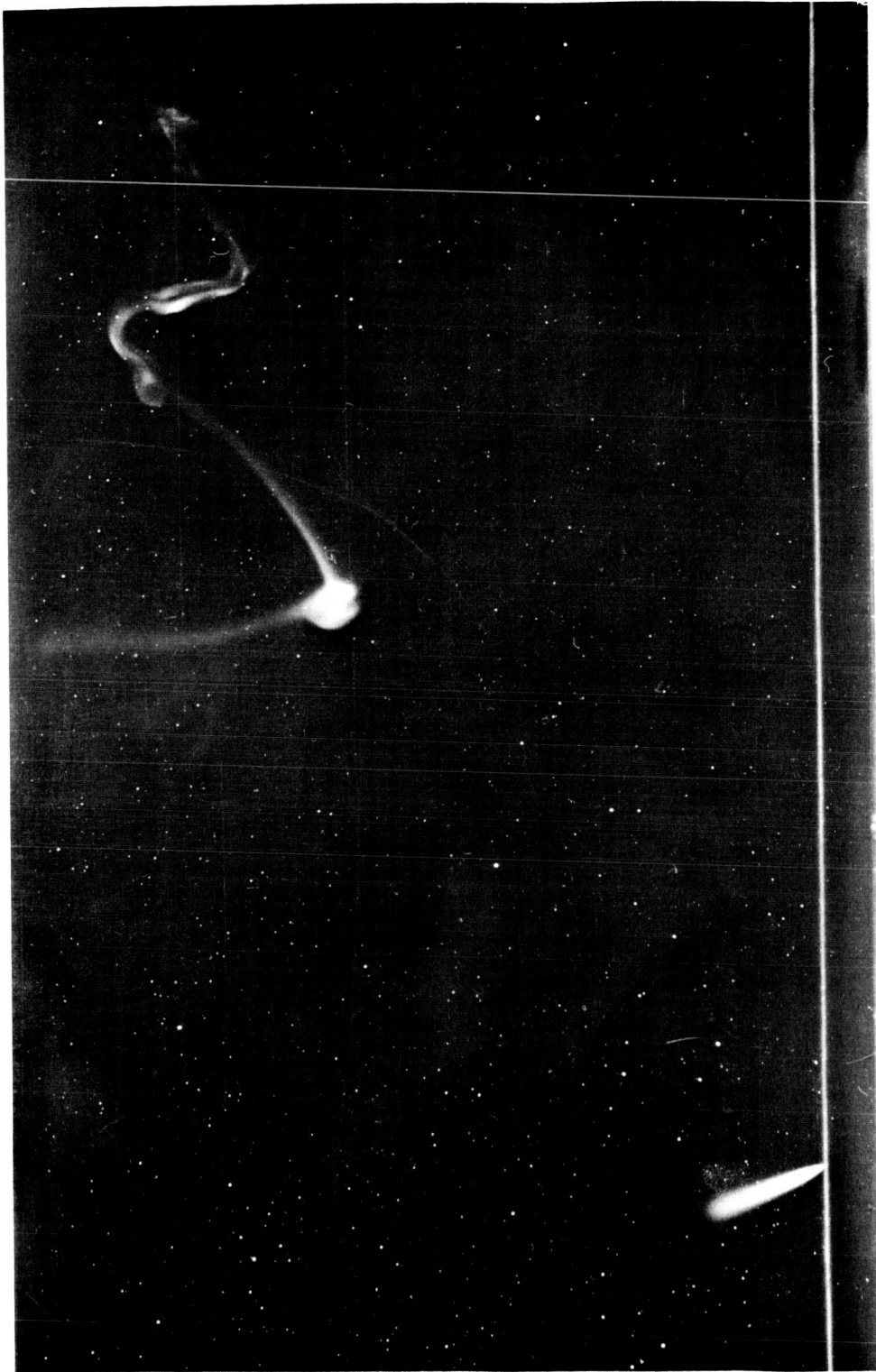


Figure 4.--Trimethylene aluminum shot of 1 November 1964 photographed at 06:22:14.



Figure 5.--Trimethylene aluminum shot of 1 November 1964 photographed at 06:26:59.

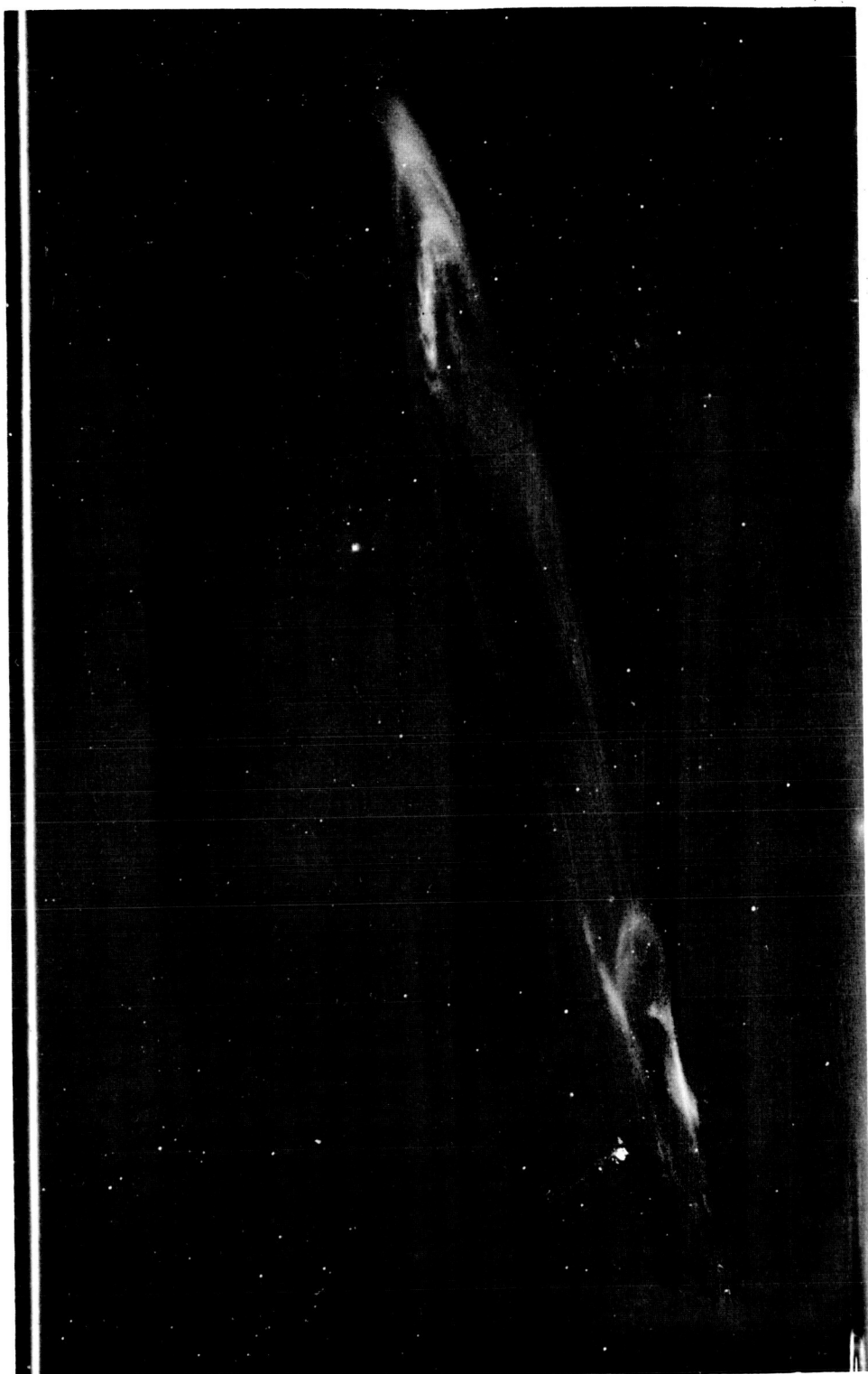


Figure 6.--Trimethylene aluminum shot of 1 November 1964 photographed at 06:39:47.



Figure 7.--Trimethylaluminum shot of 3 November 1964 photographed at 04:42:08.

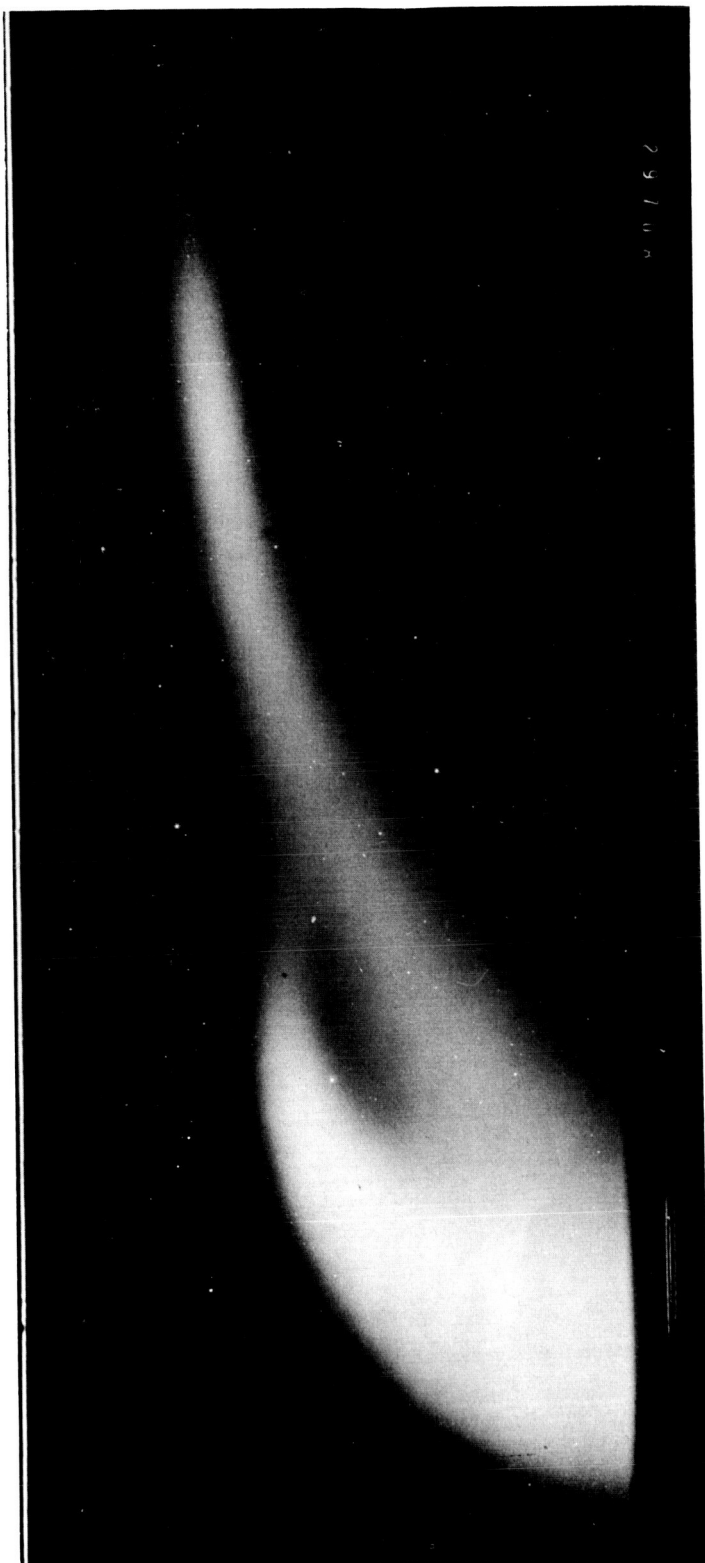


Figure 8.--Trimethylene aluminum shot of 3 November 1964 photographed at 04:47:57.

Table 1.--Chemical sodium shoot photography from Villa Dolores.  
Evening 5 November 1964 - Launch time 23:16:00 Z (20:16:00 Local)

Time	B-N Frames*	Log Remarks by Station Personnel
From 23:17:42	5 frames	Rocket spotted. Photography started.
To 23:17:58	8 sec cycle	Only a small portion of trail on film.
		Camera was moved to locate cloud on field of view better.
From 23:18:02	17 frames	Shows rocket ascending and nice contortions beginning to form in trail. Quality good.
To 23:19:09	8 sec cycle	
		Rocket moves off film. Here camera was moved slightly to center turbulent region.
From 23:19:17	16 frames	Nice trail contortions. Quality good.
To 23:20:17	8 sec cycle	
		Camera moved to center interesting region.
From 23:20:25	15 frames	Trail contortions expanding. Here interesting region is beginning to exceed five degrees width of camera field.
To 23:21:21	8 sec cycle	
23:21:25		Frame ruined because film had to be cut to process.
From 23:21:29	14 frames	Same region. Still good.
To 23:22:21	8 sec cycle	
		Camera moved here to descending cloud trail in effort to get beginning of convolutions.
From 23:22:49	9 frames	Photos of "descending" column.
To 23:23:21	8 sec cycle	
23:23:30	1 frame	This was tried to see if image quality would be better. (good, but too dark-16 sec cycle would have been ideal).
	32 sec cycle	



Table 1 (Cont.)

Time	B-N Frames*	Log Remarks by Station Personnel
From 23:23:39 To 23:24:35	8 frames 16 sec cycle	Good quality, however not too much turbulence evident. "Ascending" column getting fainter.  Here camera was positioned with field horizontal instead of vertical in effort to get both turbulent regions on field.
From 23:25:57 To 23: 6:13	3 frames 16 sec cycle	Ok
From 23:26:21	1 frame	Here shutter stopped and momentarily left open as rate changed to 32 sec cycle. Beginning to get darker.
From 23:26:42 To 23:27:46	5 frames 32 sec cycle	Seeing is getting poorer.
From 23:28:05 To 23:28:37	5 frames 16 sec cycle	Quality here not so good.  Here oriented camera long field vertically again, to try to get better coverage of ascending part, which was much better looking, (more contrast to naked eye), than downfall section, which was almost faded out.
From 23:29:30	51 frames 16 sec cycle	Photos of ascending portion. First few frames ok, but quality degenerates as sky gets very dark and stratus clouds begin to move in and merge with rocket trail.
Here follow eight frames, four with f/4 diaphragm and filter, varying cycle rates, and four with f/1 opening (no diaphragm) and no filter, varying cycle rates. Nothing is distinguishable except sodium cloud merged with stratus. This was taken as a check.		
Morning 6 November 1964 - Launch time 08:32:00 Z (05:32:00 Local) (Same filter, same diaphragm)		
From 08:33:30 To 08:34:00		Looked for rocket in same place at corresponding time as previous night. Saw nothing.

Table 1 (Cont.)

Time	B-N Frames*	Log Remarks by Station Personnel
		Rocket spotted: much higher than before.
From 08:34:32	3 frames	
To 08:34:48	16 sec cycle	No nice clean trail, only a "blob" visible.
From 08:35:04	20 frames	
To 08:37:36	16 sec cycle	Moved camera to center "blob". Disappointing.
From 08:38:12	2 frames	
To 08:38:20	16 sec cycle	Different portion of "blob" in attempt to get full portion.
		Moved camera slightly.
From 08:38:29	5 frames	
To 08:39:01	16 sec cycle	Here descending trail beginning to form. Ok, but poor cloud.
		Here relocated camera slightly to get a "V" that is beginning to form.
From 08:39:17	13 frames	
To 08:40:52	16 sec cycle	Nice, but can't get all of the "V" on field. One frame chopped in two to process. Maybe 32 sec cycle would have been better.
		Here relocated camera horizontally to get two "V's", one up-side, the other on the down-side.
From 08:41:49	10 frames	
To 08:43:01	16 sec cycle	Both "V's" covered. Best of all morning shot photos. Almost fills up field of camera. Don't know how up-rising "V's" formed as was nothing there previously.
		Here changed to eight sec cycle. Think sky was too bright.
From 08:43:11	37 frames	
To 08:45:35	8 sec cycle	Here "V's" expanded greatly but there is very little definition in sky or on film. General outline is all.
From 08:45:58	20 frames	
To 08:47:14	8 sec cycle	Here moved camera to keep "V's" on field. Shame there is no more contrast: interesting formation.

Table 1 (Cont.)

Time	B-N Frames*	Log Remarks by Station Personnel
From 08:47:59	15 frames	Chasing expanding "V" on downfall
To 08:48:55	8 sec cycle	side. Sky getting brighter.
		Tried to get vertical alignment
		to show twists lower on down
		falling side.
From 08:50:16	19 frames	Getting very bright. Interesting
To 08:50:52	4 sec cycle	twisty tail but very low contrast.
		Hardly visible due brightness.

Here cloud fades out.

\*Baker Nunn nomenclature - 4 sec cycle rate: 0.4 sec exp every 2 secs.  
 8 sec cycle rate 0.8 sec exp every 4 secs.  
 16 sec cycle rate 1.6 sec exp every 8 secs.  
 32 sec cycle rate 3.2 sec exp every 16 secs.

f/4 diaphragm has four holes each  $2\frac{1}{2}$  inches in diameter.  
 f/1 is regular 20-inch diameter lens.

Table 2.--Trimethylene aluminum field results - 3 November 1964.

<u>Time in min. after sunset</u>	<u>Cycle rate</u>	<u>Diaphragm</u>	<u>Filter</u>	<u>Magnitude faintest star</u>	<u>Background fogging</u>
start to 82	16	f/8.0	A-23	1-2	none
82 to 88	16	f/4.0	A-23	***	***
88 to 98	08	none	none	6-10	slight
98 to end	16	none	none	10-15	none

\*\*\*These settings were not used, but examination of the film exposed during this period indicates that this set would have produced good results.

Table 3.--Trimethylene aluminum shot photography  
SC12-15804 (1 November 1964)

Time	B-N Frames*	2/Cycle	Log Remarks by Station Personnel
From 06:21:58 To 06:23:10	10	16	Photography started (at 22:14, Figure 4). Reentering rocket? Cloud on all frames.  Altitude change.
From 06:23:35 To 06:24:40	8	16	Cloud on all frames (extreme right end of film).
From 06:25:54 To 06:26:26	4	16	Some useless frames (altitude change). Portion of cloud trail in center.  Change in altitude.
From 06:26:54			Figure 5 cloud in center of frame. Good quality  Trail contortions expanding, Figure 4. Main portion covering three degrees wide field.
To 06:40:50	105	16	Figure 6 at 39:46. Good photography on all frames some sky area-star field stationary camera.*
From 06:40:59 To 06:41:07	5	4	Poor (faint) inadequate exposure (experimental).  *Main section of cloud expanded to approximate by an eight degrees sky area. Appears similar to an edge on galaxy (Andromeda minus its dense nucleus).
SC12-15805 (3 November 1964)			
From 06:36:19 To 06:41:39	41	16	Red filter used. Only a dozen photos show release.

Table 3 (Cont.)

Time		B-N Frames	2/Cycle	Log Remarks by Station Personnel
From	06:42:04	10	8	No filter. Matter (poor). Good. See Figure 7 at 42:08. Portion of cloud distorted forming loop-like arrangement. Some background fog.
To	06:42:40			
From	06:46:28	32	8	Azimuth change.  Loop expanding.  Less background fog.
To	06:48:32			
From	06:50:13	17	8	Most of cloud in field of view.  Cloud diffusing some frames have been affected by light leaks.
To	06:51:21			

BAKER-NUNN TRACKING OF THE AIR DENSITY EXPLORER BALLOON  
AND THE INJUN EXPLORER SPACECRAFT<sup>1</sup>

N65 31272

by

Ellis A. Monash<sup>2</sup>

Abstract.--The Smithsonian Astrophysical Observatory was requested to track the Air Density Explorer balloon and the Injun Explorer spacecraft by the National Aeronautics and Space Administration. The inflation of the Air Density Explorer balloon and the separation of the Injun Explorer spacecraft were confirmed by the Smithsonian Astrophysical Observatory, South Africa Station.

The Smithsonian Astrophysical Observatory received nominal orbital elements on November 14, 1964, from Goddard Space Flight Center for the Air Density Explorer. From the orbital elements, two ephemerides were computed and distributed to the twelve Baker-Nunn stations via teletype. In addition, instructions were included to confirm the separation of the Air Density Explorer balloon and the Injun Explorer spacecraft from the rocket hardware, the inflation of the balloon, the number of objects placed into orbit, the apparent brightness of each piece in orbit, and an identification and position of each piece.

After the launch on November 21, 1964 at 17<sup>h</sup>09<sup>m</sup>.65 UT, a complete description of the various pieces in orbit was issued from the Smithsonian Astrophysical Observatory, South Africa Station (Station 02). They initially confirm five pieces placed into orbit at the position and time indicated by the predictions. They listed their observations of the various pieces in order of their relative positions observed in the sky.

The first piece observed appeared at 18<sup>h</sup>09<sup>m</sup>32<sup>s</sup> UT, leading the balloon by about 8.5 minutes of arc. The object flashed at a brightness of magnitude 8 with a frequency of about 0.6 sec<sup>-1</sup>. This piece is the furthest from the balloon (Figure 1) and is labeled piece A. (See Figure 4.)

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<sup>1</sup>Supported by grant number NsG 87/60 from the National Aeronautics and Space Administration.

<sup>2</sup>Physicist, Data Division, Smithsonian Astrophysical Observatory.

Piece B possessed characteristics similar to those of A. It too showed flashing, but it was brighter than piece A by one magnitude. At 18<sup>h</sup>15<sup>m</sup>.4 UT, the image of piece B on the Baker-Nunn film showed two distinct parallel trails separated by about 10 seconds of arc (Figure 2). In the plot of the relative separation of the various pieces from the balloon (Figure 1), the slope of piece B displayed a break, indicating that the Injun Explorer spacecraft separated from its housing unit. When the Injun Explorer space craft became a single entity, a Cospar number, 6407602, was assigned to it. (See Table 2 for Orbital Elements.)

The third piece, C, observed on the Baker-Nunn film is the brightest at magnitude 5. We feel that it is the balloon since it is the brightest in the group. Initially, we felt that the apparent brightness when first observed would lie in the range from third to sixth magnitude; therefore, we conclude the balloon is fully inflated as planned. The Air Density Explorer balloon is also assigned a Cospar number, 6407601. (See Table 2 for Orbital Elements.)

Piece D, the fourth piece, is considerably fainter than the balloon at an apparent brightness of magnitude 8. It also flashes as do pieces A and B, trailing the balloon by the least separation of all the pieces.

The fifth piece, Piece E, is difficult to distinguish from piece D, since it is fainter by at least one magnitude and very close to piece D on the film.

Another confirmation (Figure 3) of the various Air Density Explorer pieces shows the direct separation of four pieces for several days at Smithsonian Astrophysical Observatory Australia Station.

At present, we hope to track the Air Density Explorer for its entire life learning as much as possible from the interaction of the balloon and its environment.

#### Acknowledgments

I would like to thank Mrs. Beatrice Miller and Mr. Bob Martin for reading the manuscript and making suggestions for its improvement.

#### References

NASA Press Release, Release Number 64-284, 13 November 1964 (This report describes the scientific objectives of Air Density Explorer and Injun Explorer, the construction and characteristics of the satellites, including a description of the launch vehicle).



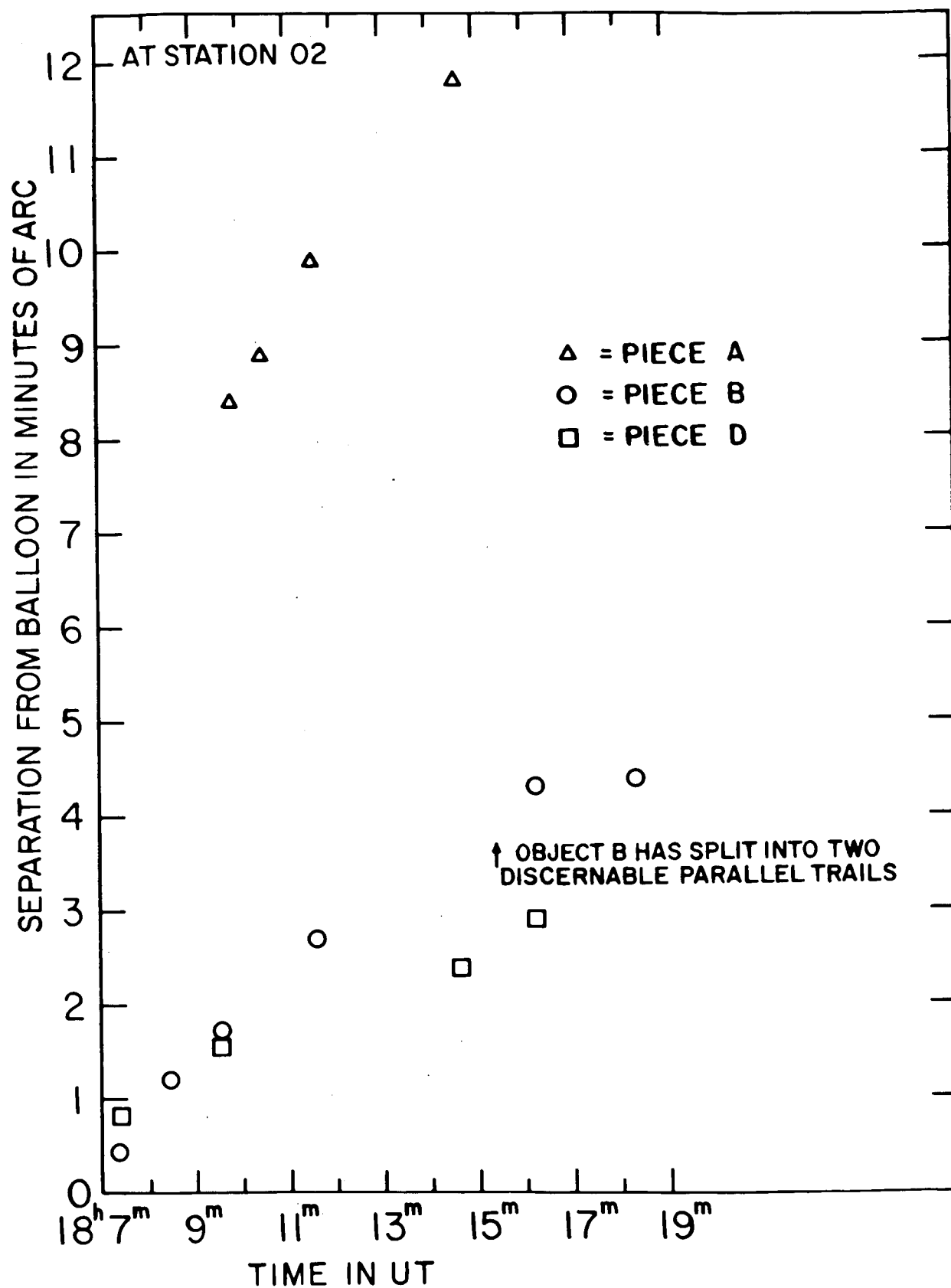


Figure 1.--Separation of pieces A, B, and D from piece C (Air Density Balloon) on 21 November 1964.

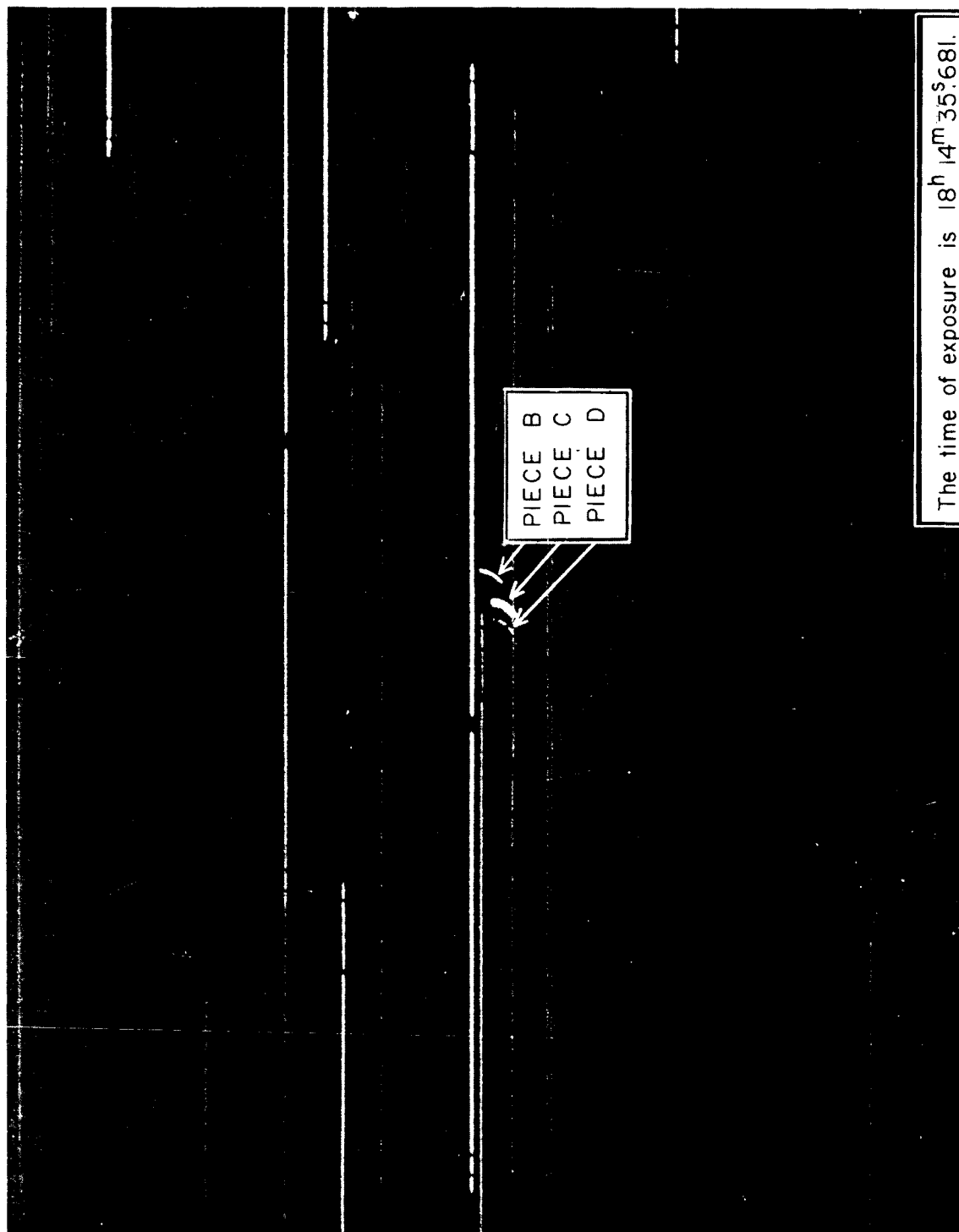
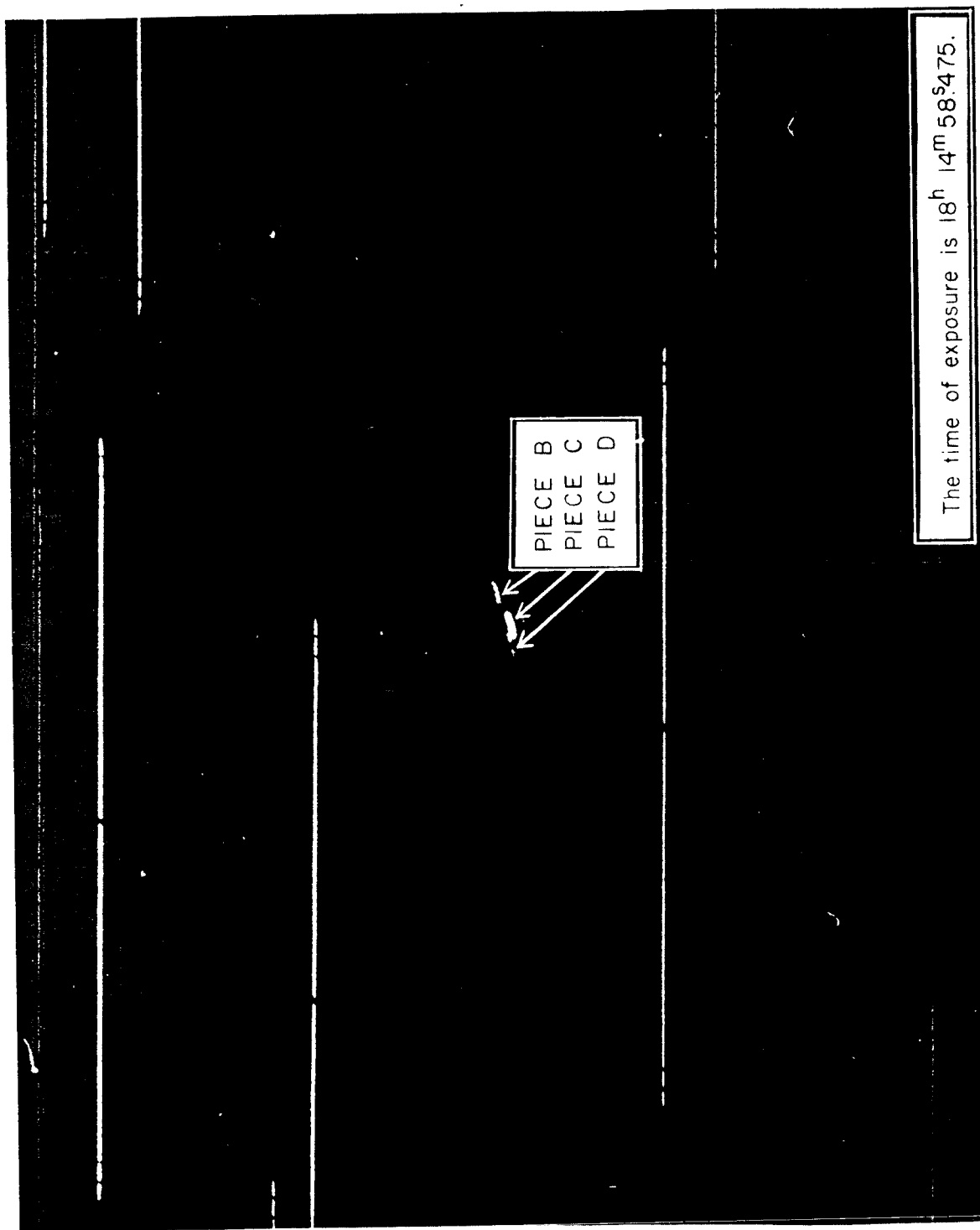


Figure 2.--Baker-Nunn photographs of Air Density Explorer Balloon and Injun Explorer spacecraft showing  
(a) the separation of Injun Explorer spacecraft from its housing.



The time of exposure is 18<sup>h</sup> 14<sup>m</sup> 58<sup>s</sup>.475.

Figure 2  
(b)

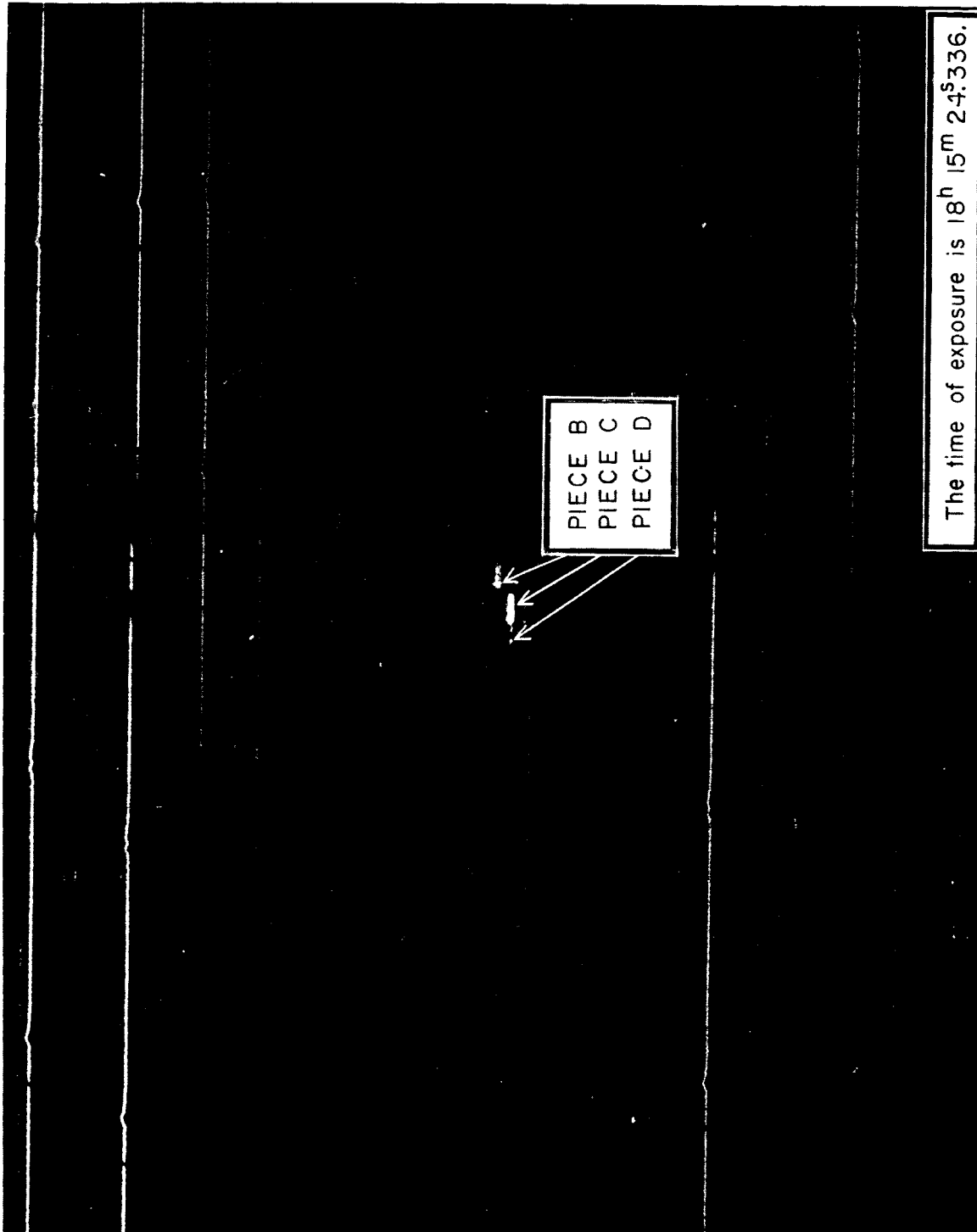


Figure 2  
(c)

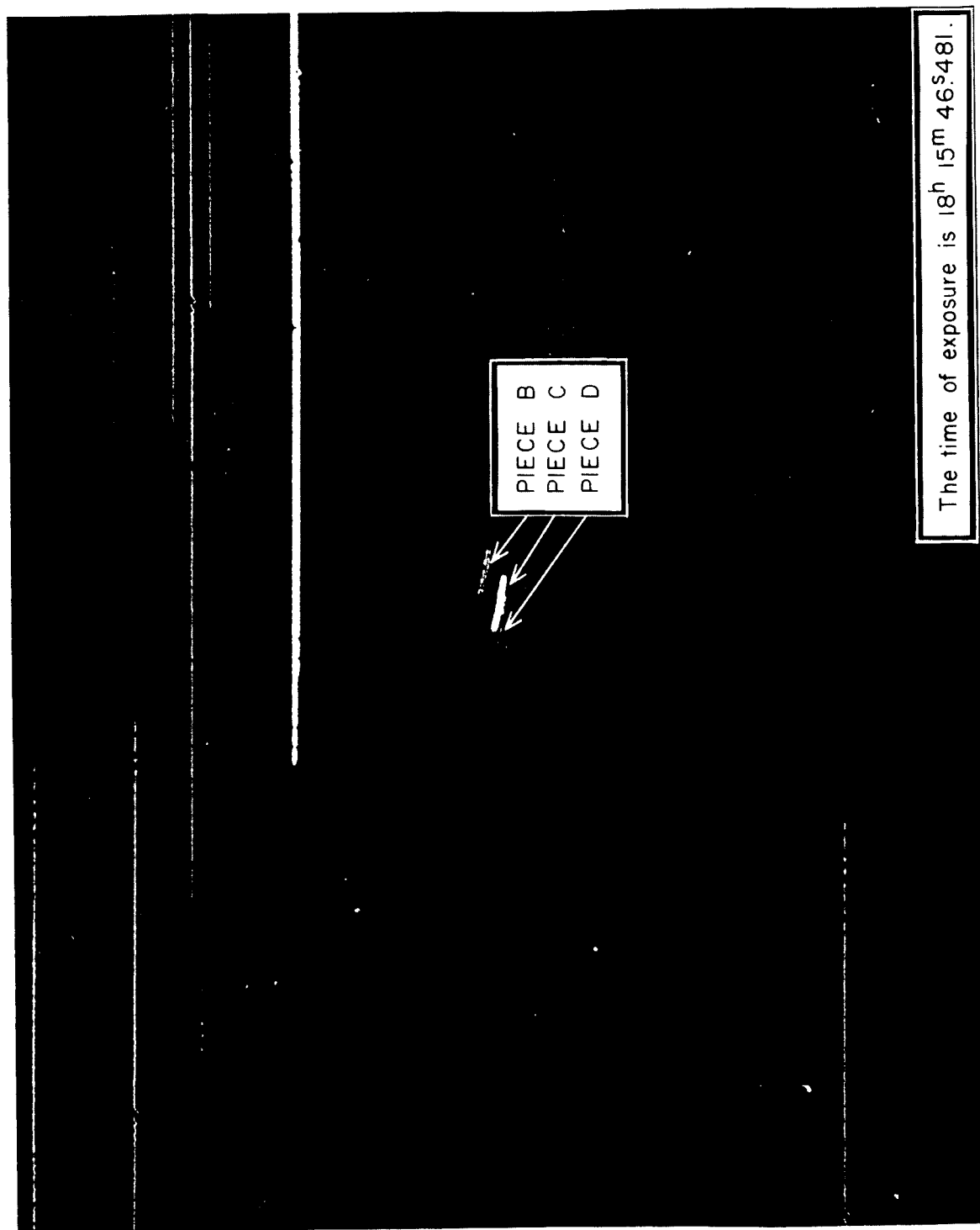


Figure 2  
(d)

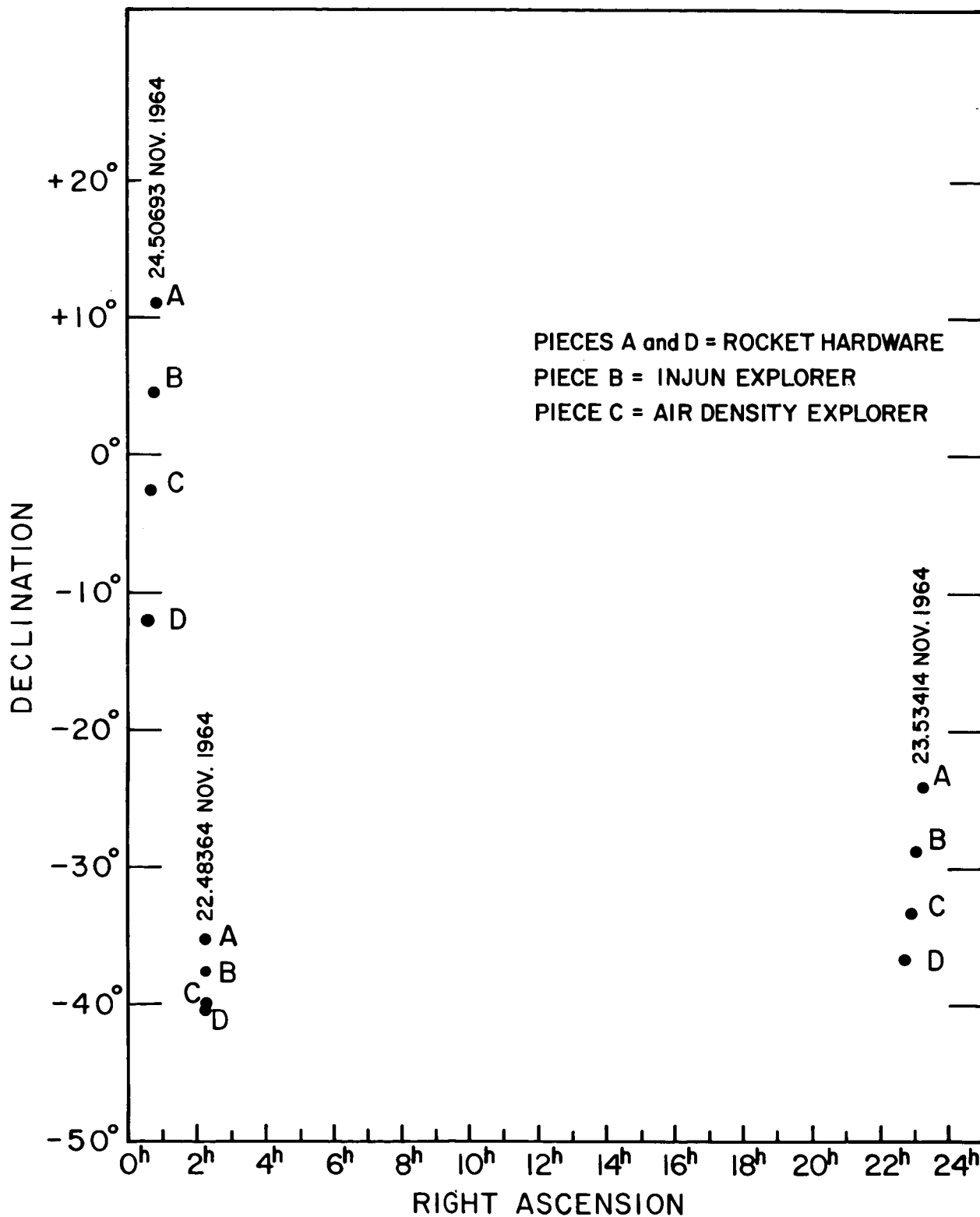


Figure 3.--Separation of the various components of the air density explorer from day to day at station 23.

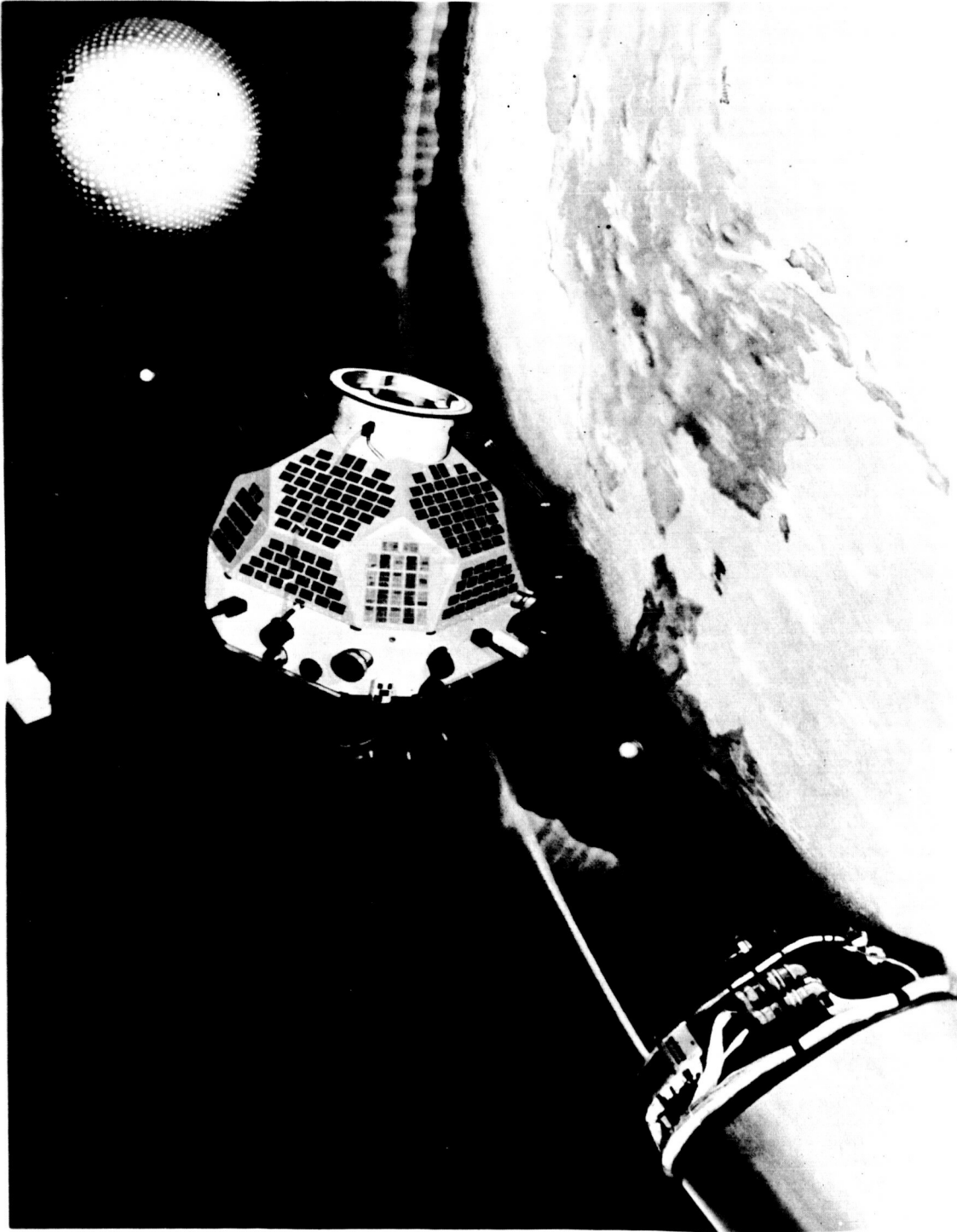


Figure 4.--Artist's conception of Air Density Explorer (upper right) and Injun Explorer Spacecraft (center) orbiting the earth. The leading piece (lower left) is the rocket casing.

Table 1

## Physical Characteristics of Air Density Explorer and Injun Explorer

Satellite	Diameter	Mass	Satellite Material	Average Satellite Density	Satellite Area-to-Mass Ratio
Air Density Explorer	366 cm	8.6 kgm	Aluminum-Mylar	$3.35(10)^{-4}$ gm cm <sup>-3</sup>	$12.2 \text{ cm}^2 \text{ gm}^{-1}$
Injun Explorer	61 cm	40 kgm	-	$3.36(10)^{-1}$ gm cm <sup>-3</sup>	$7.3(10)^{-2} \text{ cm}^2 \text{ gm}^{-1}$



Table 2

## Orbital Elements of 6407601 and 6407602

## Satellite 1964 76 A (6407601)

## I. SAO elements

The following elements are based on 80 observations and are valid for the period November 21 through December 2, 1964.

$$T_0 = 38726.0 \text{ MJD}$$

$$\omega = (155^\circ.020 \pm 94) - (2^\circ.174 \pm 28)t$$

$$\Omega = (20^\circ.5833 \pm 50) - (0^\circ.73128 \pm 97)t$$

$$i = (81^\circ.3610 \pm 98)$$

$$e = (.124978 \pm 82)$$

$$M = (.36377 \pm 33) + (12.384588 \pm 99)t + (.6162 \pm 90) \times 10^{-4}t^2 \\ - (.214 \pm 30) \times 10^{-5}t^3$$

Standard error of one observation:  $\sigma = \pm 3!02.$

## Satellite 1964 76 B (6407602)

## I. SAO elements

The following elements are based on 45 observations and are valid for the period November 21, 1964 through December 2, 1964.

$$T_0 = 38726.0 \text{ MJD}$$

$$\omega = (155^\circ.163 \pm 69) - (2^\circ.191 \pm 18)t$$

$$\Omega = (20^\circ.5722 \pm 32) - (0^\circ.73335 \pm 41)t$$

$$i = (81^\circ.3619 \pm 58)$$

$$e = (.125114 \pm 52)$$

$$M = (.39633 \pm 25) + (12.390565 \pm 64)t + (.65 \pm 45) \times 10^{-6}t^2$$

Standard error of one observation:  $\sigma = \pm 1!20$

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CHS NO	STATION	STA NO	DATE	TIME	R. A.	DECL.	AZIMUTH	ALTITUDE	RANGE	INDEX
10003	CLIFANTS	9002	64 11 21	18 04 26.76	5 48 18	-64 59				434023
10004	CLIFANTS	9002	64 11 21	18 04 00.92	4 21 48	-48 21				434023
10005	CLIFANTS	9002	64 11 21	18 10 17.92	3 56 18	-35 20				434023
10006	CLIFANTS	9002	64 11 21	18 18 14.17	3 24 54	12 33				434013
10008	LAGECN	9023	64 11 22	11 36 26.72	2 13 30	-40 03				434023
10009	LAGECN	9023	64 11 22	11 43 16.91	2 09 12	10 45				434013
10014	LAGECN	9023	64 11 23	10 50 58.72	3 41 24	-45 03				434023
10015	LAGECN	9023	64 11 23	10 59 52.32	2 57 54	11 19				434013
10016	LAGECN	9023	64 11 23	12 49 09.46	22 53 30	-33 17				434023
10017	LAGECN	9023	64 11 23	12 52 37.16	23 31 42	-9 39				434013
10018	CLIFANTS	9002	64 11 23	18 41 37.74	2 24 12	-24 00				434023
10023	V. C.	9011	64 11 24	0 25 00.98	3 24 00	-49 39				434023
10024	V. C.	9011	64 11 24	0 25 35.02	3 17 06	-45 38				434023
10025	V. C.	9011	64 11 24	0 25 51.02	3 14 12	-43 47				434023
10026	LAGECN	9023	64 11 24	12 10 06.65	0 40 36	-1 40				434013
10026	LAGECN	9023	64 11 24	14 05 10.34	22 24 42	-6 33				434013
10019	CLIFANTS	9002	64 11 24	17 53 44.98	3 53 06	-45 19				434023
10020	CLIFANTS	9002	64 11 24	19 53 22.92	23 11 54	-26 56				434023
10021	CLIFANTS	9002	64 11 24	19 54 59.18	23 25 06	-16 41				434013
10022	CLIFANTS	9002	64 11 24	19 56 50.15	23 39 30	-2 51				434013
10036	V. C.	9011	64 11 25	1 38 52.91	23 30 06	-43 33				434023
10029	AREQUIPA	9007	64 11 25	3 44 12.57	22 24 30	-5 40				434013
10030	AREQUIPA	9007	64 11 25	3 44 20.57	22 25 12	-5 00				434013
10031	AREQUIPA	9007	64 11 25	3 45 13.42	22 29 06	-0 51				434013
10046	LAGECN	9023	64 11 25	11 22 01.59	1 49 00	-35 09				434023
10047	LAGECN	9023	64 11 25	11 24 19.66	1 48 18	-16 16				434013
10048	LAGECN	9023	64 11 25	13 20 31.70	22 33 54	-12 23				434013
10049	LAGECN	9023	64 11 25	13 22 59.07	22 52 54	0 18				434013
10028	CLIFANTS	9002	64 11 25	21 06 17.58	22 04 30	-15 27				434013
10037	V. C.	9011	64 11 26	0 53 15.25	1 25 12	-11 24				434013
10032	CURACAC	9009	64 11 26	1 08 02.40	2 29 48	-37 00				434023
10038	V. C.	9011	64 11 26	2 52 15.20	22 00 00	-24 03				434023
10039	CURACAC	9009	64 11 26	3 05 12.76	22 49 30	-25 02				434023
10039	HARESTUA	9115	64 11 26	5 40 39.14	17 29 12	34 57				434013
10040	HARESTUA	9115	64 11 26	5 40 47.14	17 20 48	33 22				434013
10041	HARESTUA	9115	64 11 26	5 40 55.14	17 12 48	31 47				434013
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10052	LAGECN	9023	64 11 26	12 34 25.71	22 43 48	-29 49				434023
10053	CLIFANTS	9002	64 11 26	20 22 05.80	22 16 18	-20 56				434013
10062	CURACAC	9009	64 11 27	0 23 31.70	3 27 18	-34 43				434023
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10066	V. C.	9011	64 11 27	2 06 10.28	21 47 36	-42 27				434023
10067	V. C.	9011	64 11 27	2 09 40.20	22 41 42	-22 05				434013
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10071	LAGECN	9023	64 11 28	13 01 39.09	21 40 54	-30 20				434023
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10079	CLIFANTS	9002	64 11 28	20 47 59.42	21 25 42	-27 37				434023
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10083	MAUI	9012	64 11 29	6 44 02.66	2 06 36	-36 43				434023
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10097	AREQUIPA	9007	64 12 02	2 34 06.37	22 18 36	-25 54				434023
10098	CURACAC	9009	64 12 02	2 39 12.37	22 17 00	0 37				434013
10105	MAUI	9012	64 12 02	6 31 26.88	1 50 18	-21 57				434013
10106	MAUI	9012	64 12 02	8 25 46.58	22 33 06	-24 27				434023
10107	MAUI	9012	64 12 02	8 28 09.13	22 30 00	-13 34				434013
10099	LAGECN	9023	64 12 02	12 03 44.25	22 12 30	-28 45				434023

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OBS NO	STATION	STA NO	DATE	TIME	R. A.	DECL.	AZIMUTH	ALTITUDE	RANGE	INDEX
10033	OLIFANTS	9002	64 11 21	18 08 00.92	4 21 54	-48 19				434023
10004	OLIFANTS	9002	64 11 21	18 10 02.93	3 57 30	-36 08				434023
10005	OLIFANTS	9002	64 11 21	18 18 14.17	3 24 48	12 34				434013
10266	LAGOON	9023	64 11 22	11 36 26.72	2 13 48	-35 13				434023
10267	LAGOON	9023	64 11 22	11 43 16.51	2 10 42	14 00				434013
10269	LAGOON	9023	64 11 23	10 50 58.72	3 29 30	-35 53				434023
10269	LAGOON	9023	64 11 23	10 59 52.32	2 58 48	17 36				434013
10270	LAGOON	9023	64 11 23	12 49 09.46	23 13 36	-24 10				434023
10271	LAGOON	9023	64 11 23	12 52 39.16	23 43 42	- 0 51				434013
10222	LAGOON	9023	64 11 25	11 17 46.78	1 58 00	-47 07				434023
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10226	LAGOON	9023	64 11 26	12 29 57.82	22 34 30	-36 34				434023
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10235	LAGOON	9023	64 11 28	11 02 33.83	1 38 42	-30 21				434023
10236	LAGOON	9023	64 11 28	12 57 37.02	21 55 24	-26 48				434023
10241	OLIFANTS	9002	64 11 28	18 50 01.71	0 25 00	-25 02				434023
10227	AREQUIPA	9007	64 11 29	0 42 03.71	2 32 24	-20 11				434013
10228	AREQUIPA	9007	64 11 29	0 42 43.71	2 32 00	-15 02				434013
10239	OLIFANTS	9002	64 11 29	18 04 26.30	1 56 12	-32 56				434023
10239	OLIFANTS	9002	64 11 29	18 05 15.84	1 55 30	-26 11				434023
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10253	V. DOLOR	9011	64 12 01	1 02 41.08	23 15 54	-36 40				434023
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10255	V. DOLOR	9011	64 12 01	1 05 12.33	23 40 06	-17 26				434013
10247	AREQUIPA	9007	64 12 01	1 10 07.04	0 48 54	-15 31				434013
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10244	JOHNSTON	9117	64 12 01	7 07 20.01	2 44 48	-21 56				434013
10245	JOHNSTON	9117	64 12 01	7 07 44.01	2 46 42	-19 23				434013
10245	JOHNSTON	9117	64 12 01	7 08 00.01	2 47 54	-17 34				434013
10256	LAGOON	9023	64 12 01	10 45 08.34	1 21 42	-31 59				434023
10257	LAGOON	9023	64 12 01	10 47 46.44	1 23 48	-10 30				434013
10258	LAGOON	9023	64 12 01	12 40 22.51	21 45 18	-26 15				434023
10259	AREQUIPA	9007	64 12 02	0 24 49.52	2 18 12	-20 12				434013
10260	AREQUIPA	9007	64 12 02	0 25 21.52	2 17 54	-15 53				434013
10261	AREQUIPA	9007	64 12 02	0 25 53.52	2 17 54	-11 36				434013
10262	CURACAO	9009	64 12 02	0 33 53.94	2 19 48	-14 18				434013
10263	CURACAO	9009	64 12 02	2 30 05.78	22 24 36	-10 42				434013
10264	LAGOON	9023	64 12 02	11 58 40.48	22 46 24	-14 32				434013